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Corporate Governance and Sustainability: The Moderating Role of Board Gender Diversity in the Relationship Between Environmental Innovation and Emission Performance

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Abstract

This study examines the effect of environmental innovation on emission performance and the moderating role of board gender diversity among firms in the Middle East and North Africa (MENA) region. Using a panel dataset of 2319 firm-year observations from 13 countries between 2013 and 2024, the analysis applies fixed-effects regression and robustness checks using the Generalized Method of Moments (GMM). The findings show that environmental innovation significantly improves emissions performance, confirming its strategic role in achieving sustainability goals. Board gender diversity has a positive direct impact on emissions outcomes, suggesting that diverse boards enhance sustainability-oriented governance. However, the interaction term has a negative and significant effect, indicating that gender diversity, while beneficial overall, can weaken the link between environmental innovation and emission performance, possibly because of complex decision-making processes. This study contributes theoretically by extending the Resource-Based View and Porter Hypothesis to an under-researched context, while emphasizing the need for governance mechanisms that leverage diversity without slowing innovation implementation. Future research should incorporate qualitative insights and examine other governance factors to deepen our understanding of how board composition influences sustainability strategies.

Keywords: environmental innovation; emission performance; board gender diversity; corporate governance; MENA region

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1. Introduction

In the modern business dimension, environmental innovation has taken the stage as a critical factor in corporate sustainability and stewardship of the environment [1]. This involves the development and introduction of new products, procedures, methods, and corporate strategies that result in decreased destruction of the environment or increased

efficiency in the way resources are used [2]. As the issues of climate change, diminishment of natural resources, and regulation increase, companies are required to incorporate new procedures to address the environmental problems [3]. A self-assessment of greenhouse gas and secondary emission performance, based on an organization's ability to reduce them, has also begun to be a key predictor of corporate responsibility as regards the environment [4]. Improving the performance of emissions is not only a method of meeting regulatory requirements but also improves the image and market standings of companies engaged in the markets where sustainability-based practice is fast gaining acceptance among both consumers and investor groups [5]. The recent process of global environmental agreements, including the Paris Agreement and the United Nations Sustainable Development Goals (SDGs), has gone a notch higher to emphasize the importance of environmental innovation as a strategic responsibility of a company that is gripped with furthering global environmental climate mitigation interests [6].

Theoretically, the association between environmental innovation and emissions performance is likely to be significant or positive [2]. Environmental innovation, in turn, involves attempts to mitigate the harmful ecological effects of cleaner technologies, energy-efficient processes, and better waste management systems [7]. Companies that invest in eco-innovative processes are in a more advantageous position to reduce emissions, abide by strict environmental regulations, and meet the market and social demands for sustainability [3]. Such process innovations, such as the deployment of renewable energy or carbon capture technologies, would also directly aim to reduce emissions, whereas product innovations, such as energy-efficient appliances or low-emission vehicles, would do so indirectly [1]. Moreover, innovation leads to the introduction of constant improvements and learning in organizations so that they can respond to ever-changing environmental challenges. Thus, the greater the involvement of a firm in environmental innovation, the more likely it is to perform better in emissions and develop long-term environmental resilience [8].

Although environmental innovation is likely to be correlated with emission performance, the empirical evidence is inconclusive. Many studies have shown that the relationship between environmental innovations and emissions is strong, with a positive correlation indicating that implementing environmental innovations in firms results in lower emission levels and enhanced environmental performance measures [9,10]. These conclusions are typically described by the fact that innovation can help achieve operating efficiencies, lower energy use, and better adherence to environmental rules and regulations [8]. However, other studies have shown weak, inconsistent, or even negative relationships [11]. For example, the future advantages of environmental innovation can be far in the future, as the costs of its application are high, the technology is not yet fully tested, or the managerial experience is insufficient [9]. Environmental industry-specific dynamics, regulatory environments, and variations in firms' strategic priorities may affect the extent to which environmental innovation is transformed into actual emission outcomes [12]. These inconsistent findings demonstrate the multifaceted nature of the association between innovation and performance, and the requirement to explore situational factors that can influence this association.

Lack of clarity in the available literature is especially keen in the context of the Middle East and North Africa (MENA) region, where there is an evident paucity of research investigation on environmental innovation and emissions performance [13]. This gap in the literature is notable considering that the region is highly dependent on fossil-fuel production and consumption, the nascent nature of its regulatory environment, and the increasing urgency to diversify economies and strengthen the sustainability agenda [4]. Despite MENA countries being ratified to international agreements, such as the Paris Agreement,

there is significant heterogeneity between the regulation frameworks and enforcement systems [14]. In addition, corporate governance and strategic orientations toward environmental issues are shaped by cultural and institutional norms, which make the region an important but lesser-explored context to study the nexus at the boundary of innovation and emission results [15]. This research gap is critical not only to moral advancement in terms of the theoretical perspective but is also needed to provide the knowledge base of empirically supported expertise that can equip policymakers and corporate leaders to develop the mechanics of sustainable operations in the MENA economies that are in transition.

The aspect of corporate governance, especially board structure and makeup, has been introduced as a leading factor that affects strategic choices of a company, and various of these choices are also applicable to environmental innovation and performance [16]. Board gender diversity is one of the governance properties that has illustrated a lot of interest both in scholarly literature and regulatory practice [17]. Gender diversity boards are hypothesized to expand the range of opinions, improve the quality of decisions, and increase awareness of the environment and social issues [18]. Empirical studies show that female directors especially have higher ethical behavior, long-term orientation, and increased tendency to invest in sustainability programs [19]. As a result, the inclusion of gender diversity in the boardroom can be a positive moderator which strengthens the relationship between environmental innovation and emission performance, due to promotion of scrutiny, responsibility, as well as promotion of environmental ambition [20]. Additionally, heterogeneous boards are in a better position to allocate resources to innovative initiatives in a more compelling manner, as well as facilitating the same to ensure useful implementation, consequently amplifying the effects of innovation [17].

Nevertheless, the influence of board gender diversity as a moderator may be unclear [21]. Although diversity may lead to more creativity and problem-solving, it also poses certain issues, as the decision-making process may take more time, and the existing differences in opinion may cause conflicts [22]. Such dynamics can contribute to a decrease in the effectiveness of implementing innovative strategies [23], especially in environments where gender diversity has recently been established and cultural guidelines for gender roles are still conservative, which is true for most countries in the MENA region [24]. Therefore, the association between gender diversity and ecological innovation may yield different results, which require empirical research. This mitigating effect is vital to gaining sophisticated knowledge about how governance instruments can shape the emission performance of companies, particularly in regions in the development of socioeconomic transformation and seeking to become more sustainable [25,26].

Thus, this study presents empirical evidence on these relationships based on a large panel of firms in the MENA region, multi-country, multi-industry, and multi-period. The results indicate that environmental innovation has a positive and significant influence on emission performance, which is in line with the fact that companies that invest in innovative environmental strategies achieve better environmental performance. Nonetheless, the analysis also reveals that board gender diversity has a mixed moderating effect: boards that are more diverse in terms of gender are largely linked to better emission performance, but environmental innovation has reduced positive effects on emission outcomes in the presence of gender diversity on boards. This implies that despite the valuable governance and sustainability commitments associated with gender diversity, it can also lead to governance processes that complicate the process of turning innovative strategies into emission reductions.

This study contributes to literature in several ways. First, it fills an important research gap with evidence from the MENA region, which lacks studies on environmental innovation and emission performance [27,28]. Second, it contributes to theoretical knowledge by

illustrating that governance features, namely board gender diversity, do not universally improve innovation performance but have a more subtle and context-specific effect [19]. Finally, the results have applied consequences for legislators and business leaders with reference to the importance of governance structures that balance diversity and strategic alignment in the effective implementation of environmental innovations [29,30]. These contributions highlight the need to not only focus on new approaches but also on new systems of governance to reach better corporate environmental operation in emerging and transitioning economies.

This paper is arranged as follows: Section 2 offers a literature review and reviews the key concepts and prior research relevant to the study. Section 3 draws the theoretical foundation and hypothesis development. Section 4 details the investigation method, including the data collection and measurement of variables. Section 5 shows the outcomes and discussion; Section 6 concludes the study.

2. Literature Review

2.1. Review of Environmental Innovation Impacts on Emission Performance

Environmental innovation is a strategic priority for corporations across the globe, as they endeavor to meet global sustainability goals and act in accordance with increasingly strict environmental regulations [2]. This means that it is the creation and application of new or greatly enhanced processes, goods, services, or organizational approaches that will help minimize environmental degradation [10]. Environmental innovation is not merely technological innovation but also managerial innovation and includes practices that lower emissions, increase energy efficiency, and minimize waste [7]. In theory, environmental innovation leads to improved environmental performance in terms of reducing harmful emissions and improving operational efficiency [5]. Moreover, strict environmental regulations can encourage innovation, which covers the costs of meeting requirements and increasing competitiveness [31]. Companies that invest in environmental innovation will have a chance to gain two benefits: to comply with regulatory restrictions and enhance their competitive position in the market based on resource efficiency and cost reduction [32].

Prior investigators have increasingly investigated the connection between environmental innovation and emission performance, recognizing innovation as a crucial driver for achieving environmental sustainability [33,34]. Empirical evidence suggests that organizations implementing green technologies and eco-friendly production methods experience significant reductions in greenhouse gas emissions, thereby improving their large emission performance [35]. These results emphasize the magnitude of innovation in easing the process of adherence to environmental standards and meeting stakeholder requirements on sustainability [3]. However, alternative views have now presented compelling evidence with certain studies showing inconclusive or no effect in support of the current assumption of universal status of this relation [36]. These inconsistencies are explained by various factors, such as the time difference between the implementation of new practices and the impact that they have on emissions, the great price and risk of technological change, and the unequal regulatory environment that differs by country and industry [7]. Additionally, some companies might use environmental innovation as a signaling system instead of a conduit to make significant emissions cuts, thereby constraining its utilization value [12].

This linkage between innovation and environmental performance in developing and emerging economies has not been thoroughly studied in the Middle East and North Africa (MENA) region [28]. The present condition in the region is poverty-rich dependence on fossil fuels, underdeveloped adoption of environmental policies, and unstable governance systems, all of which together present a unique institutional environment and can influence the efficiency of environmental innovation [24]. Even though MENA countries have

made promises to global climate agreements, their path to low-emission economies have been characterized by delays [14]. Together with the influence of cultural and socio-political factors, this institutional uncertainty poses a fundamental challenge to the ability of environmental innovation to deliver similar results in high levels of emission cuts in MENA, as noted in developed markets [13]. As a result, greater insight into this relationship is urgent to create policies and corporate solutions that will be effective in promoting the process of the sustainability transition in the region.

2.2. Board Gender Diversity as Moderator

Gender diversity in business boards has become one of the decisive sides of CG, and it faces growing interest among regulators, scholars, and delegates [37]. It is simply described as a group of women being chosen as a part of the board and is usually seen as a way of facilitating better quality of decisions and corporate responsibility [38]. Within the framework of environmental sustainability, gender-diverse boards were linked to increased sensitivity to social and environmental issues, increased ethical values, and a long-term strategic perspective [39]. The attributes are indicative of the fact that variations in gender could affect the ability of a firm to engage in environmental endeavors and realize better outcomes on the level of emissions [40]. Practical studies have revealed that gender-diverse boards will be more fascinated by investing in green technologies, adoption of ends up with environmental management systems, and responding to stakeholders who compel businesses to release sustainability information [17,18]. Interestingly, better performance indicators and sustainability reporting are registered by companies that have high gender representation on their boards than those that have low gender representation on their boards [16]. These results indicate that female directors are proactive participants in sustainability strategy development, thus possibly enhancing the nexus between environmental innovation and emission reduction [19,22].

Nonetheless, the moderating effect of gender diversity on the link between environmental innovation and emission performance remains under-explored, with sparse and inconsistent evidence [17]. Some research proposes that diversity increases innovation performance through better supervision and optimizes the use of resources in environmental priorities [37,39,40]. Others, however, indicate that diverse boards can be slow in decision-making or can be involved in internal conflict, which can make it less efficient to implement complicated innovations, such as green technologies [22,32]. This inconclusive evidence underscores the necessity of more research into the impact of gender diversity on the translation of innovation into quantifiable environmental impacts [41]. The problem is especially critical when it comes to the Middle East and North Africa (MENA) region, where gender representation in corporate boards is still low and the institutional practices around gender roles are still strong [42]. Although most MENA territories have employed regulations and rules to improve woman representation on the board, the process has been progressing slowly; women are still subject to obstacles in full participation in strategic decision-making [24]. Such cultural and institutional limitations might have implications for the effectiveness of gender-diverse boards in contributing to sustainability goals [13]. Consequently, the moderating effect of gender mixes on boards is not well known, and very limited empirical evidence is available. Filling this gap is essential for understanding the association involving governance structures, innovation, and environmental performance in an emerging region where both sustainability and gender equality are burning policy priorities.

3. Theoretical Background and Hypotheses Development

3.1. Environmental Innovation and Emission Performance

Interestingly, environmental innovation and emission performance are two concepts that have received much scholarly interest, but their interaction remains a controversial topic in terms of strength, directionality, and mechanistic details [2]. According to advocates, environmental innovation can be understood as the development of introducing innovative or improved technologies, processes, and practices to minimize environmental degradation, providing companies with an opportunity to achieve a high level of environmental and operational performance [7,22]. These innovations can help mitigate both regulatory and societal pressures by reducing emissions and improving energy efficiency, in addition to creating strategic benefits in the long term [27]. Critics, however, argue that innovation alone does not ensure instant emission reductions because the price of implementation, technological uncertainties, and organizational obstacles may limit the effectiveness of innovation [9,10]. Porter's theory offers a strong point of departure for analyzing the role of environmental innovation. It assumes that strict, well-designed ecological policies will foster innovation that counterbalances the cost of doing so and improves competitiveness [43]. From this perspective, companies involved in environmental innovation are expected to gain twofold: avoid regulatory penalties and have a cleaner environment, including reduced emissions [22]. This claim is supported by empirical observations in advanced economies, in which innovation-led companies tend to lead their counterparts in terms of sustainability [19,32]. However, counterarguments point out that these results are dependent on the existence of powerful institutional frameworks and effective regulatory enforcement conditions, which are not equal across regions [35].

Moreover, the resource-based view (RBV) provides an alternative approach, stating that environmental innovations are valuable and rare resources that are inimitable and can be used to generate sustained competitive advantages [44]. From this perspective, companies that can incorporate eco-innovations in their business will perform better in their emissions because they will be more resource-efficient and less wasteful [45]. Critics maintain that not every technology is an environmental innovation according to RBV criteria; some technologies are easily imitable or demand substantial complementary resources and capabilities to deliver any quantifiable impact [46]. Based on these arguments, although environmental innovation should theoretically lead to better emission performance, the strength of this relationship is an open empirical question, especially in the MENA region, where institutional, cultural, and economic dynamics may shape things differently. However, considering the weight of theoretical reasoning and supportive evidence from previous studies, there is a likelihood of finding a positive association concerning these two variables. Therefore, the first hypothesis is proposed.

H1: *There is a positive relationship between Environmental innovation and emission performance.*

3.2. The Moderating Effect of Gender Diversity

Although environmental innovation could be a technical and strategic resource in emission reduction, it is not only the innovation that leads to success, but also the governance mechanisms that facilitate proper implementation [36]. Board gender diversity, a major feature of corporate governance, has been closely associated with better sustainability performance, as gender-diverse boards are considered to have a broader scope and understanding, be more independent, and sensitive to environmental and social issues [37,39]. Empirical evidence indicates that as far as female representation in boardrooms increases, firms are more likely to have greater sustainability practices and hence disclose more environmental information and perform better in terms of the environment [17,24]. This implies

that gender diversity may increase the positive influence of environmental innovation by enhancing accountability and establishing long-term environmental goals [19]. However, this assumption remains unquestioned. Although diversity is linked to greater creativity and oversight, it can add complexity, slower decision-making, and potential conflict among directors, which may slow the speedy and efficient implementation of innovative strategies [22]. The result of gender diversity is also complex in the context of MENA [27], where women in boardrooms are underrepresented, and gender role institutional norms may limit the ability of women to influence high-level strategic decisions [47]. This results in the probability that the moderate impact of gender diversity is not always positive or consistent across regions. Although there have been some uncertainties regarding gender diversity, the weight of the evidence seems to indicate that gender diversity tends to favor sustainability-oriented strategies. Based on this, we propose the subsequent hypothesis:

H2: *Board gender diversity moderates the relationship between environmental innovation and emission performance.*

4. Study Method

4.1. Sample and Data Collection

The study utilized a panel dataset with 2319 firm-year observations from public companies in 13 nations within the MENA region, encompassing Turkey, Saudi Arabia, the United Arab Emirates, Qatar, and Egypt. The sample duration is 12 years, from 2013 to 2024, to provide a detailed analysis of the temporal dynamics of environmental innovation, governance systems, and emission performance. Industry representation was conducted according to the TRBC industry and economic sector categories, which were diverse in sectors but represented dominance in specific sectors like financials (32.51%), real estate (12.25%), and basic materials (10.48%). The data were obtained through the Refinitiv Eikon (Thomson Reuters), which is a well-known financial and ESG database with standardized firm-level data on ESG practices [48]. Firms with incomplete data on key variables are omitted to maintain data integrity [16,22,27]. The final sample was chosen based on the availability of reasonably consistent environmental innovation, emission performance, and corporate governance data over the observation period and countries [38]. This large sample of figures permits for a strong analysis of the hypothesized relations with respect to institutional disparities across countries and sector-specific dynamics within the MENA region. Table 1 shows the geographical allocation of the sample firms through the MENA region.

Table 1. Tabulation of Country of Exchange.

Country of Exchange	Freq.	Percent	Cum.
Bahrain	85	3.67	3.67
Egypt	163	7.03	10.69
Israel	167	7.20	17.90
Jordan	30	1.29	19.19
Kuwait	128	5.52	24.71
Lebanon	2	0.09	24.80
Morocco	153	6.60	31.39
Oman	83	3.58	34.97
Qatar	251	10.82	45.80
Saudi Arabia	326	14.06	59.85

Table 1. *Cont.*

Country of Exchange	Freq.	Percent	Cum.
Tunisia	2	0.09	59.94
Turkey	615	26.52	86.46
United Arab Emirates	314	13.54	100.00
Total	2319	100.00	

Table 1, Tabulation of Country of Exchange, shows the geographical distribution of the 2319 observations. There is a high concentration of samples in several key countries. The highest percentage of observations belongs to Turkey (26.52%), Saudi Arabia (14.06%), and the United Arab Emirates (13.54%). Taken together, these three countries make up more than half of the sample. On the other hand, mostly underrepresented countries are Lebanon and Tunisia, with only 0.09 percent contribution to the observations. Qatar, Egypt, Israel, and Morocco together comprise the rest of the sample at a moderate percentage of between 6.60 and 10.82 percent each. The concentration in several countries indicates that the outcomes of the research are more likely relevant in these countries' economic and regulatory settings. In addition, the sample is divided into industries in accordance with TRBC (Thomson Reuters Business Classification) and presented in Table 2.

Table 2. Tabulation of TRBC Industry Name.

TRBC Industry Name	Freq.	Percent	Cum.
Advanced Medical Equipment & Technology	2	0.09	0.09
Aerospace & Defense	8	0.34	0.43
Agricultural Chemicals	9	0.39	0.82
Airlines	19	0.82	1.64
Airport Operators & Services	8	0.34	1.98
Aluminum	6	0.26	2.24
Apparel & Accessories	3	0.13	2.37
Apparel & Accessories Retailers	14	0.60	2.98
Appliances, Tools & Housewares	15	0.65	3.62
Auto & Truck Manufacturers	14	0.60	4.23
Auto Vehicles, Parts & Service Retailers	17	0.73	4.96
Auto, Truck & Motorcycle Parts	12	0.52	5.48
Banks	254	10.95	16.43
Biotechnology & Medical Research	6	0.26	16.69
Brewers	12	0.52	17.21
Broadcasting	12	0.52	17.72
Business Support Services	36	1.55	19.28
Casinos & Gaming	12	0.52	19.79
Commercial Printing Services	4	0.17	19.97
Commercial REITs	2	0.09	20.05
Commodity Chemicals	36	1.55	21.60
Communications & Networking	2	0.09	21.69
Computer & Electronics Retailers	2	0.09	21.78
Computer Hardware	3	0.13	21.91
Construction & Engineering	68	2.93	24.84

Table 2. *Cont.*

TRBC Industry Name	Freq.	Percent	Cum.
Construction Materials	108	4.66	29.50
Construction Supplies & Fixtures	19	0.82	30.31
Consumer Goods Conglomerates	35	1.51	31.82
Consumer Lending	25	1.08	32.90
Consumer Publishing	24	1.03	33.94
Corporate Financial Services	36	1.55	35.49
Courier, Postal, Air Freight & Land-based Logistics	13	0.56	36.05
Discount Stores	6	0.26	36.31
Diversified Chemicals	5	0.22	36.52
Diversified Investment Services	30	1.29	37.82
Diversified REITs	16	0.69	38.51
Drug Retailers	3	0.13	38.64
Electric Utilities	22	0.95	39.59
Electrical Components & Equipment	11	0.47	40.06
Employment Services	12	0.52	40.58
Entertainment Production	5	0.22	40.79
Financial & Commodity Market Operators & Service Providers	3	0.13	40.92
Financial Technology (Fintech)	12	0.52	41.44
Fishing & Farming	21	0.91	42.35
Food Processing	133	5.74	48.08
Food Retail & Distribution	28	1.21	49.29
Healthcare Facilities & Services	34	1.47	50.75
Heavy Machinery & Vehicles	7	0.30	51.06
Home Furnishings	5	0.22	51.27
Homebuilding	3	0.13	51.40
Hotels, Motels & Cruise Lines	37	1.60	53.00
Household Products	4	0.17	53.17
IT Services & Consulting	10	0.43	53.60
Independent Power Producers	16	0.69	54.29
Industrial Machinery & Equipment	8	0.34	54.64
Integrated Oil & Gas	8	0.34	54.98
Integrated Telecommunications Services	15	0.65	55.63
Investment Banking & Brokerage Services	44	1.90	57.52
Investment Holding Companies	32	1.38	58.90
Investment Management & Fund Operators	113	4.87	63.78
Iron & Steel	51	2.20	65.98
Leisure & Recreation	12	0.52	66.49
Life & Health Insurance	28	1.21	67.70
Marine Freight & Logistics	28	1.21	68.91
Marine Port Services	8	0.34	69.25
Medical Equipment, Supplies & Distribution	4	0.17	69.43
Miscellaneous Educational Service Providers	11	0.47	69.90
Multiline Insurance & Brokers	98	4.23	74.13
Multiline Utilities	7	0.30	74.43
Natural Gas Utilities	2	0.09	74.51
Non-Alcoholic Beverages	17	0.73	75.25

Table 2. *Cont.*

TRBC Industry Name	Freq.	Percent	Cum.
Non-Paper Containers & Packaging	11	0.47	75.72
Office Equipment	2	0.09	75.81
Oil & Gas Drilling	7	0.30	76.11
Oil & Gas Exploration and Production	17	0.73	76.84
Oil & Gas Refining and Marketing	29	1.25	78.09
Oil & Gas Transportation Services	5	0.22	78.31
Oil Related Services and Equipment	12	0.52	78.83
Paper Packaging	6	0.26	79.09
Paper Products	9	0.39	79.47
Passenger Transportation, Ground & Sea	16	0.69	80.16
Pharmaceuticals	22	0.95	81.11
Phones & Handheld Devices	1	0.04	81.16
Property & Casualty Insurance	81	3.49	84.65
Real Estate Rental, Development & Operations	256	11.04	95.69
Real Estate Services	7	0.30	95.99
Reinsurance	10	0.43	96.42
Renewable Energy Equipment & Services	8	0.34	96.77
Restaurants & Bars	3	0.13	96.90
Semiconductors	6	0.26	97.15
Software	8	0.34	97.50
Specialized REITs	3	0.13	97.63
Specialty Chemicals	2	0.09	97.71
Textiles & Leather Goods	16	0.69	98.40
Tobacco	1	0.04	98.45
Water & Related Utilities	3	0.13	98.58
Wireless Telecommunications Services	33	1.42	100.00
Total	2319	100.00	

As is indicated in the second table (Table 2), Tabulation of TRBC Industry Name, the sample is divided into industries. The observations are spread over a broad spectrum of industries, with a few covering the sample. The largest industries are Real Estate Rental, Development & Operations (11.04%), banks (10.95%), Construction Materials (4.66%), and Investment Management & Fund Operators (4.87%). More than a quarter of the total sample comprises these four industries. The rest of the industries (Advanced Medical Equipment & Technology, Aerospace & Defense, Agricultural Chemicals) are represented by a very low amount, with each having less than 1% of the observations. Such an uneven distribution with a wide scope indicates that the study represents a broad scope of business activity, but the findings may be skewed by the dynamics of the most represented sectors. Table 3 presents the industry breakdown at a more aggregated level, where firms are classified into more general economic sectors.

Lastly, the third table (Table 3), Tabulation of TRBC Economic Sector Name, provides an overview of the industry distribution at a higher level. This tabulation verifies the predominance of certain sectors in the sample. The most evident sector is financials, with 32.51 percent of the observations, followed by Real Estate (12.25%), Industrials (10.61%), and Basic Materials (10.48%). Most of the samples were from the four sectors. However, Academic & Educational Services and Utilities are insignificant, with less than 2.5 percent

of the total number of observations. This sectoral disaggregation shows that the research is strongly inclined toward financial and real estate companies, which can affect the general results and their further application in other industries of the economy.

Table 3. Tabulation of TRBC Economic Sector Name.

TRBC Economic Sector Name	Freq.	Percent	Cum.
Academic & Educational Services	11	0.47	0.47
Basic Materials	243	10.48	10.95
Consumer Cyclicals	231	9.96	20.91
Consumer non-cyclicals	254	10.95	31.87
Energy	86	3.71	35.58
Financials	754	32.51	68.09
Healthcare	68	2.93	71.02
Industrials	246	10.61	81.63
Real Estate	284	12.25	93.88
Technology	92	3.97	97.84
Utilities	50	2.16	100.00
Total	2319	100.00	

4.2. Variables and Measurement

Emission performance in this research denotes the ability of a firm to decrease greenhouse gas (GHG) emissions and accomplish environmental sustainability enhancement through effective management practices and strategic initiatives [4,5]. It is quantified using the Refinitiv Eikon Emissions Score, which rates companies in relation to transparency, emission reduction policies, and performance results [49]. The scale is between 0 and 100, and the higher the score, the better the company aligns with global sustainability practices and the more it is doing to cut emissions. Similarly, environmental innovation refers to the innovation or adoption of novel or meaningfully improved products, procedures, or organizational approaches that reduce environmental harm or degradation, including pollution, emissions, or excessive use of resources [8,9,27]. The Refinitiv Eikon Environmental Innovation Score was used as a measure of this variable, which is an index that considers activities at the firm's level, investments in technologies, and eco-efficient operation of a business of promoting green innovation [50]. Similarly to the score on emissions, it is rated on a 0–100 scale, where a bigger number shows a stronger devotion to environmentally friendly innovation. Board gender diversity can be described as females on the board of directors of a particular firm and is one of the greatest principal areas of diversity in CG [24,37]. It is evaluated as a proportion of female directors, thus acting as an indicator of sex-inclusive and sex-diversified participation in the planned decision-making procedure [19]. Last, the research balances the number of other factors that could affect the emissions performance, including the CSR sustainability rating, the presence of an ecological management team, SDG 7 membership, and the board size [16,32,38,51]. It is in that light that, through incorporating these control variables, the proposed analysis should help isolate the effect of environmental innovation moderated by the board gender diversity factor and address other corporate governance and sustainability-related factors.

4.3. Model Specification

To examine the direct effect of environmental innovation and other factors on emission performance, the following baseline panel regression model was specified:

Direct effect:

$$\text{Emissionit} = \beta 0 + \beta 1\text{ENVINNit} + \beta 2\text{CSRit} + \beta 3\text{ENVMGTit} + \beta 4\text{SDG7it} + \beta 5\text{BSizeit} + \epsilon\text{it}$$

Indirect effect:

$$\text{Emissionit} = \beta 0 + \beta 1\text{ENVINNit} + \beta 2\text{BGNDit} + \beta 3\text{BGND*ENVINNit} + \beta 4\text{CSRit} + \beta 5\text{ENVMGTit} + \beta 6\text{SDG7it} + \beta 7\text{BSizeit} + \epsilon\text{it}$$

The first specification assesses the direct impact of environmental innovation and sustainability-related factors on emission performance, while the second investigates whether the connection between environmental innovation and emission performance is contingent upon board gender diversity. The study variables are presented in Table 4.

Table 4. Variable definition.

Variables	Abbreviations	Measurements
Emission performance	Emission	Emission performance score—Evaluates how effectively a company works toward and achieves reductions in environmental emissions.
Environmental innovation	ENVINN	Environmental innovation score—indicates a company's ability to decrease environmental costs and impacts on its customers, fostering new market opportunities through innovative environmental technologies, processes, or eco-friendly products.
Board gender diversity	BGND	Ratio of female representation among all board members.
CSR sustainability	CSR	CSR sustainability score—Measures the existence of a CSR committee or specialized team, focusing on board or senior executive committees charged with CSR strategy development and implementation.
Environmental management teams	ENVMGT	Presence or absence of environmental management teams. 1 for presence and 0 for absence
Sustainable Development Goal 7	SDG 7	If the company discloses information related to SDG 7 (Affordable and Clean Energy), code as 1; otherwise, code as 0.
Board size	BSize	The total number of board members at the end of the fiscal year.

5. Results

5.1. Descriptive Statistics

Table 5 provides the descriptive statistics of the study variables using 2319 firm-year observations. The mean value of the Emission Performance Scale is 31.739, with a standard deviation of 32.112, which shows that there is a significant variation among firms. The fact that the lowest value is 0 and the highest value is 93.478 indicates that, although there are firms with good emission performance, there are also those with no observable improvements. The mean of environmental innovation, ENVINN, was 20.741, and the standard deviation was 29.126, implying a large variance in the degree of environmental innovation by firms. Likewise, board gender diversity (BGND) is 9.222%, implying that women make up less than 10 percent of the board members on average, and with a maximum of 33.333%.

This means that gender diversity is not high in the MENA region. The mean value of the CSR sustainability score is 12.527 with a large standard deviation (26.867), indicating inconsistent involvement in the CSR of different firms. The mean values of the binary variables' environmental management teams, ENVMGT, and SDG 7 engagement are 0.389 and 0.234, respectively, which means that less than half of the firms have dedicated environmental management teams, and only about 23 percent actively participate in affordable and clean energy initiatives. Lastly, Board Size (BSize) has an average of 9.475 members, with a range of 0–26, which shows that governance structures are variable. In general, descriptive statistics serve as a solid foundation for regression analysis, as marked heterogeneity in sustainability practices, governance, and environmental strategies is revealed across firms.

Table 5. Descriptive Statistics.

Variable	Obs.	Mean	Std. Dev.	Min	Max
Emission	2319	31.739	32.112	0	93.478
ENVINN	2319	20.741	29.126	0	85.714
BGND	2319	9.222	10.838	0	33.333
CSR	2319	12.527	26.867	0	80
ENVMGT	2319	0.389	0.488	0	1
SDG7	2319	0.234	0.423	0	1
BSize	2319	9.475	2.806	0	26

Note: Emission = emission performance, ENVINN = environmental innovation, BGND = board gender diversity, CSR = CSR sustainability score, ENVMGT = environmental management team, SDG7 = SDG 7 affordable and clean energy, BSize = board size.

5.2. Pairwise Correlations

Table 6 describes the pairwise correlation coefficients of the research variables. The findings revealed some significant relationships. The correlation between emissions performance and environmental innovation (ENVINN) is positive and significant (r = 0.608, $p < 0.01$), indicating that firms with higher environmental innovation are more likely to perform better in terms of emissions. Similarly, board gender diversity (BGND) is positively related to emission performance (r = 0.341, $p < 0.01$) and environmental innovation (r = 0.285, $p < 0.01$), which suggests that gender-diverse boards are generally associated with stronger sustainability practices. The Environmental Management Team (ENVMGT) was significantly positively correlated with emission performance (r = 0.628, $p < 0.01$) and environmental innovation (r = 0.472, $p < 0.01$), indicating that specialized environmental governance structures are important. Involvement in SDG 7 (Affordable and Clean Energy) also showed a strong positive correlation with emission performance (r = 0.458, $p < 0.01$) and environmental innovation (r = 0.333, $p < 0.01$), underlining the role of renewable energy efforts in sustainability performance. On the other hand, Board Size (BSize) is weakly correlated with most variables, including a small negative correlation with CSR (r = −0.071, $p < 0.01$) and SDG 7 (r = −0.072, $p < 0.01$), indicating that board size does not necessarily contribute to sustainability performance. In general, the correlations suggest that multicollinearity is not a concern, and the results of the VIF values [16,22] (Table 7) confirm this conclusion, as all values are below the critical level.

Table 6. Pairwise correlations.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(1) Emission	1.000						
(2) ENVINN	0.608 ***	1.000					

Table 6. *Cont.*

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)
(3) BGND	0.341 ***	0.285 ***	1.000				
(4) CSR	0.142 ***	0.095 ***	0.089 **	1.000			
(5) ENVMGT	0.628 ***	0.472 ***	0.279 ***	0.124 ***	1.000		
(6) SDG7	0.458 ***	0.333 ***	0.209 ***	0.181 ***	0.324 ***	1.000	
(7) BSize	0.128 ***	0.132 ***	0.017	−0.071 *	0.061 ***	−0.072 ***	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 7. Variance inflation factor.

	VIF	1/VIF
ENVINN	1.412	0.708
ENVMGT	1.376	0.727
SDG7	1.223	0.818
BGND	1.133	0.883
CSR	1.045	0.957
BSize	1.039	0.962
Mean VIF	1.205	.

5.3. Regression Procedures

To identify the correct estimation method for panel data, two specification tests were conducted. Initially, a Breusch and Pagan Lagrangian Multiplier (LM) test was applied to evaluate the pooled OLS model against the random-effects model [31] (See Tables 8 and 9). The findings revealed a significant chi-square value (2738.96, $p = 0.0000$), which rejected the null hypothesis and affirmed that panel data estimation is more appropriate than pooled OLS. Subsequently, the Hausman test was employed to select between fixed-effects and random-effects modeling approaches [19,38]. The test resulted in a chi-square statistic of 63.686 and a *p*-value of 0; therefore, the null hypothesis that random effects are appropriate was rejected. Thus, the fixed-effects model was used, which considers unobserved, time-invariant, firm-specific heterogeneity, making it unbiased and consistent in the parameter estimates [22].

Table 8. Hausman (1978) [38] specification test.

	Coef.
Chi-square test value	63.686
p-value	0

Table 9. Breusch and Pagan Lagrangian multiplier test for random effects.

	Coef.
Chi-square test value	2738.96
p-value	0.0000

5.4. Regression Results

The fixed-effects regression results indicate substantial evidence supporting the hypothesized relationships (See Table 10). The direct effects model reveals that the influence

of environmental innovation (ENVINN) on emission performance is positive and highly significant (0.290, $p < 0.01$), meaning that the higher the level of environmental innovation, the better the emission performance is. This finding is in line with the theoretical basis of the Porter hypothesis and the resource-based view (RBV). The Porter Hypothesis asserts that properly crafted environmental regulations motivate companies to implement innovations that not only allow them to comply with the regulations but also improve their competitiveness and operational efficiency [43]. This is evidenced by the positive and significant link involving environmental innovation and emission performance, whereby companies that invest in eco-innovative technologies and processes achieve better emission performance [52]. This finding is consistent with the claim that environmental innovation can transform regulatory and societal pressures into efficiency and competitive advantages [2,27]. These findings are also uniform with the resource-based view, which argues that businesses acquire sustainable competitive advantage through resources and experiences that are beneficial, rare, unique, and non-substitutable [46]. Environmental innovation is a strategic resource because it involves specialized knowledge, investment, and incorporation into organizational routines [36]. The positive relationship between innovation and emission outcomes is significant, meaning that companies that utilize such capabilities can attain higher environmental performance, further increasing their legitimacy and stakeholder trust. This perspective aligns with prior empirical investigation by Long et al. (2017) [53] and Anser et al. (2020) [54], who highlighted environmental capabilities as key strategic assets for competitive positioning.

Table 10. Regression Results.

	Fixed Effect		**Fixed Effect with Robust Standard Error**		**Two-Way Fixed Effect**	
Variables	**Direct**	**Moderating**	**Direct**	**Moderating**	**Direct**	**Moderating**
ENVINN	0.290 ***	0.326 ***	0.290 ***	0.326 ***	0.241***	0.287 ***
	(0.0189)	(0.0238)	(0.0482)	(0.0238)	(0.0182)	(0.0226)
BGND		0.230 ***		0.230 ***		0.088
		(0.0622)		(0.0622)		(0.0596)
ENVINN * BGND		−0.004 ***		−0.004 ***		−0.004 ***
		(0.0013)		(0.0013)		(0.0012)
CSR	0.067 ***	0.067 ***	0.067 *	0.067 ***	0.010	0.009
	(0.0215)	(0.0214)	(0.0349)	(0.0214)	(0.0207)	(0.0207)
ENVMGT	14.729 ***	14.647 ***	14.729 ***	14.647 ***	12.647 ***	12.600 **
	(1.0849)	(1.0813)	(2.4463)	(1.0813)	(1.0345)	(1.0318)
SDG7	12.546 ***	12.312 ***	12.546 ***	12.312 ***	6.373 ***	6.559 ***
	(0.9276)	(0.9374)	(1.7635)	(0.9374)	(0.9989)	(0.9989)
BSize	−0.499 ***	−0.523 ***	−0.499	−0.523 ***	0.352 *	0.334 *
	(0.1800)	(0.1795)	(0.3239)	(0.1795)	(0.1805)	(0.1803)
Constant	20.954 ***	19.396 ***	20.954 ***	19.396 ***	−4.938	−5.254
	(1.8698)	(1.9143)	(3.3694)	(1.9143)	(8.6412)	(8.6259)
Observations	2319	2319	2319	2319	2319	2319
Country FE	NO	NO	NO	NO	YES	YES
Firm FE	NO	NO	NO	NO	YES	YES
Year FE	NO	NO	NO	NO	YES	YES

Table 10. *Cont.*

	Fixed Effect		Fixed Effect with Robust Standard Error		Two-Way Fixed Effect	
Variables	**Direct**	**Moderating**	**Direct**	**Moderating**	**Direct**	**Moderating**
R-squared	0.383	0.388	0.383	0.388	0.8956	0.8963
Number of Id	487	487	487	487	487	487
F-Stat	226.3	165	35.69	165	31.03	31.10
Prob > F	0	0	0	0	0.000	0.000

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

The empirical consequences provide strong ratification of Hypothesis 1 (H1) according to which the positive impact of environmental innovation on the emission performance of firms is assumed. These findings denote that companies allocating larger sums to environmental innovation are always associated with better emission results as per the theory. The positive correlation proves the hypothesis that eco-innovative technologies and practices are not just about regulatory compliance. Instead, they promote operational efficiency and provide competitive advantage, which is consistent with the Porter Hypothesis. The empirical evidence, therefore, strongly supports H1, which depicts that environmental innovation is a critical contributor to high levels of emission performance.

When the moderating model was introduced, the coefficient of ENVINN remained positive and significant ($\beta = 0.326$, $p < 0.01$), reinforcing its importance as a driver of emission performance. Board gender diversity (BGND) also demonstrates a positive and significant direct effect ($\beta = 0.230$, $p < 0.01$), advocating that gender-diverse boards are generally associated with better environmental outcomes. However, the interaction term ENVINN × BGND is negative and significant ($\beta = -0.004$, $p < 0.01$), implying that board gender diversity weakens the positive association between environmental innovation and emissions performance. This conclusion entails that, even though gender-diverse boards are typically linked to a more pronounced ethical focus and a more sustainable-sensitive orientation, the heterogeneity of perspectives can make it difficult to convert environmental innovations into quantifiable results. Diverse boards usually take more time to deliberate, build more consensus, and negotiate competing priorities, which slows implementation of innovative projects. These dynamics are exacerbated in the MENA environment, where gender-based institutional and cultural obstacles further limit the power of female directors, thus slowing down and diminishing the speed and effectiveness with which environmental innovations enhance emission performance [24,37]. The findings also provide support for Hypothesis 2 (H2), which proposed that board gender diversity (BGND) moderates the link between environmental innovation (ENVINN) and emission performance.

Among the control variables, the presence of an Environmental Management Team (ENVMGT) ($\beta = 14.647$, $p < 0.01$) and engagement with SDG 7 (Affordable and Clean Energy) ($\beta = 12.312$, $p < 0.01$) strongly enhanced emission performance. Conversely, Board Size (BSize) negatively impacts emissions performance ($\beta = -0.523$, $p < 0.01$), representing that larger boards may be less efficient in implementing sustainability initiatives. The R-squared value (0.388) for the moderating model indicated that the explanatory variables collectively accounted for approximately 38.8% of the variation in emission performance. The F-statistics were highly significant (Prob > F = 0), confirming the overall robustness of the models.

5.5. Additional Test: Generalized Method of Moments (GMM)

To validate the strength of the results and mitigate the possible endogeneity issue, this study utilized a dynamic panel-data estimation methodology based on the Generalized Method of Moments (GMM) [55]. Endogeneity may be produced by omitted variables, a simultaneous relationship between environmental innovation and emission performance, or the persistence of emission performance over time [56]. These concerns are tempered by the GMM strategy, which incorporates lagged dependent variables as instruments and controls for unobserved heterogeneity [57,58]. The GMM estimation results in Table 11 verify the validity of the fundamental relationships established in the fixed-effects model, considering the dynamic consequences and probable endogeneity. The coefficient on the lagged dependent variable (L. Emission) is significantly positive and highly significant ($\beta = 0.425$, $p < 0.01$), which implies a high persistence in emission performance. This implies that past performance regarding emissions has a strong impact on the present performance of a firm, indicating the path-dependent nature of sustainability practices [59]. The positive and significant coefficient of environmental innovation (beta = 0.222, $p < 0.01$) in the moderating model attests to its importance as a determinant of emission performance. Firms that make environmental innovation still record better emission results, even when dynamic and endogeneity issues are considered. This result implies that companies that are involved in environmental innovation (through the incorporation of cleaner technologies, process innovations, and eco-friendly behaviors) are always associated with superior environmental performance. It is noteworthy that this is a positive relationship even when the possibility of dynamic effects and endogeneity issues are taken into consideration, which means that the impact observed is not just a result of reverse causality or unobservable firm-specific reasons.

Table 11. Generalized Method of Moments.

	(1)	(2)
Variables	**Direct Effect**	**Moderating Effect**
L. Emission	0.421 ***	0.425 ***
	(0.0361)	(0.0387)
ENVINN	0.181 ***	0.222 ***
	(0.0203)	(0.0282)
BGND		0.148 ***
		(0.0522)
ENVINN * BGND		−0.004 ***
		(0.0013)
CSR	−0.013	−0.015
	(0.0248)	(0.0254)
ENVMGT	3.627 ***	3.511 ***
	(1.1504)	(1.1359)
SDG7	4.461 ***	4.552 ***
	(0.7371)	(0.7856)
BSize	−0.283 **	−0.296 ***
	(0.1183)	(0.1148)
Constant	14.713 ***	13.851 ***
	(1.8088)	(1.9284)
Observations	1396	1396
Number of Id	340	340
AR (1)	0.000	0.000
AR (2)	0.10	0.1073

Standard errors in parentheses *** $p < 0.01$, ** $p < 0.05$.

Board gender diversity has a positive and significant effect on emissions performance ($\beta = 0.148$, $p < 0.01$), suggesting that gender-diverse boards are generally correlated with improved sustainability outcomes. However, the interaction term ENVINN × BGND remains negative and highly significant ($\beta = -0.004$, $p < 0.01$), confirming that gender diversity weakens the positive effect of environmental innovation on emissions performance. This consistency with the fixed effects model strengthens confidence in the robustness of the moderation effect. Among the control variables, the presence of an Environmental Management Team (ENVMGT) ($\beta = 3.511$, $p < 0.01$) and engagement in SDG 7 (Affordable and Clean Energy) ($\beta = 4.552$, $p < 0.01$) continued to significantly increase emission performance. Conversely, Board Size has a negative result ($\beta = -0.296$, $p < 0.01$), suggesting that larger boards may hinder effective sustainability strategy implementation. The Arellano–Bond serial correlation tests validate the GMM specification: AR (1) is significant ($p = 0.000$), as expected, whereas AR (2) is non-significant ($p = 0.1073$), confirming the absence of second-order serial correlation and the validity of the instruments. Overall, the GMM results reinforce the main findings and demonstrate robustness, confirming that environmental innovation improves emission performance, board gender diversity plays a complex role, and sustainability outcomes are influenced by dynamic firm behavior.

6. Conclusions

The main purpose of this study was to understand how environmental innovation affects the performance of emissions and to explore how the moderating impact of gender diversity on the board of directors within companies in the MENA region influences the relationship between environmental innovation and emission performance. This study utilized a fixed-effects regression model on a panel dataset comprising 2319 firm-year observations in 13 countries over 12 years with robustness checks using the Generalized Method of Moments (GMM). The findings are highly empirical in demonstrating that environmental innovation has a positive and significant impact on emissions performance, demonstrating its importance in the achievement of sustainability targets. Moreover, board gender diversity has a positive direct impact on emission performance, indicating that gender-diverse boards are linked with better environmental performance. Nonetheless, the interaction term demonstrated a negative (and significant) coefficient, which implies that gender diversity positively impacts overall sustainability governance, but mitigates the positive correlation between environmental innovation and emission performance. These results emphasize the complexity of converting innovative environmental approaches to concrete performance results when different forms of governance are applied.

Theoretically, this research advances the literature by confirming and generalizing the resource-based view (RBV) and Porter's hypothesis in an under-explored setting. The outcomes of this analysis support the view that environmental innovation as a strategic capability can generate superior emission performance, which forms a long-term competitive advantage. In addition, the study provides a subtle meaning for corporate governance by indicating that gender diversity, though beneficial in most ways, may come with other difficulties in terms of implementing innovation effectively. This brings additional complexity to the discussion of board diversity, offering the idea that its impact is not always positive but rather contingent on the region in which the cultural and institutional norms and values influence the way boards operate. In practice, this research will be useful to policymakers, regulators, and corporate leaders in developing countries. This highlights the necessity of formulating governance systems that encourage the capitalization of diversity without overlooking strategic focus and implementation.

To fully capitalize on the benefits of gender diversity, companies should implement mechanisms that ensure diverse perspectives translate into effective strategic action. This

includes establishing structured decision-making processes, such as clear communication channels and conflict resolution protocols, to avoid delays or disagreements that may arise from diverse viewpoints. In addition, training programs and workshops can help board members develop a shared understanding of environmental strategies and sustainability objectives, ensuring alignment between innovative initiatives and governance practices. Regulators and policymakers can also play a role by encouraging firms to adopt gender diversity policies alongside board development initiatives, rather than treating diversity as a compliance measure. By doing so, gender-diverse boards can serve as catalysts for environmental innovation while improving overall emission performance.

Despite its contributions, this study had some limitations that should be addressed in future research. First, the analysis was based on secondary data provided by Refinitiv Eikon and might not be representative of all qualitative dimensions of the environmental approach and board dynamics. Further research may combine primary data findings (via interviews or surveys) to provide a more in-depth understanding of the behavioral and cultural contributions to board decision-making. Second, the sample size is restricted to publicly traded companies in MENA, which can be seen as a limitation that limits the applicability of the results to other situations, such as non-listed companies or developed economies. Future research should replicate this study in an alternative institutional setting to validate and compare the results. Third, further limitations of the study are the unbalanced industry representation in the sample. A significant fraction of the observations is represented by financial and real estate companies, whereas high-emission industries (energy and manufacturing) are underrepresented. This lack of balance limits the extrapolation of the results to the emission-intensive industries. This limitation should be tackled by future research efforts that include proportionally more firms in the energy and manufacturing sectors to offer more sector-specific information. Fourth, due to data limitations and sample distribution, we did not conduct heterogeneity analyses across countries and industries. Future research could explore such sub-group analyses to identify specific context differences and provide more nuanced insights. Finally, other governance characteristics such as board independence, expertise in sustainability, and ownership structure were not considered as moderating variables. Future research should investigate these variables and determine whether they enhance the correlation between environmental innovation and emissions performance. Furthermore, longitudinal qualitative research may provide more in-depth insights into how gender-diverse boards must maneuver through the challenges of realizing sustainability innovations.

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